Variable Stars in the Local Group
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Variable Star Monitoring in Local Group Dwarf Irregular Galaxies

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Abstract. Dwarf galaxies in the local group provide a unique astrophysical laboratory. Despite their proximity some of these systems still lack a reliable distance determination as well as studies of their stellar content and star formation history. We present first results of our survey of variable stars in a sample of six local group dwarf irregular galaxies. Taking the Leo A dwarf galaxy as an example we describe observational strategies and data reduction. We discuss the lightcurves of two newly found δ Cephei stars and place them into the context of a previously derived P-L relation. Finally we discuss the LPV content of Leo A.

1. Introduction

A magnitude limited complete census of variable stars in nearby dwarf galaxies allows important contributions to the star formation history of these systems. Measurements of some variable stars can supply improved distance determinations for the host galaxies, others will provide important constraints for the population analysis. Different classes of variables can further improve the understanding of the star formation history of these system, functioning as tracers of star formation during different epochs. We expect the data set of our long term monitoring program to be especially well suited to study the contents of red long-period variables and to re-investigate the paucity of Cepheids with $P > 10$ days as reported by Sandage & Carlson (1985).

2. Observations and data reduction

We selected a sample of six local group dwarf irregular galaxies which are visible with the 0.8 m telescope of our institute at Mt. Wendelstein. The names and additional data from the literature compilation by Mateo (1998) are shown in Table 1.

The observations so far were carried out in R and B-Band, sparsely sampling a three year period starting with test observations in 1999. This part of the data set should be sensitive for long period variable stars with periods up to ~ 500 days. Additional observations in R, B and I-Band were obtained during 3 observing campaigns at the 1.23 m telescope on Calar Alto densely sampling three two week long periods. These observations should provide a ground for

Table 1. Names, variable star counts, absolute B-Band brightness in mag, and current distance estimation in kpc for the dwarf galaxies observed in our project. The data are taken from the literature compilation by Mateo (1995). For Leo A the data are from the work of Dolphin et. al (2002) and from this work.

		RR Lyr	δ Cep	LPV	M_B	distance
LGS 3	(Pisces)	–	–	–	-9.9	810 ± 60
UGCA 92	(EGB 0427+63)	–	–	–	-11.6	1300 ± 700
DDO 69	(Leo A)	8	66 *+1*[1]	*16*[1]	-11.3	690 ± 100
DDO 155	(GR 8)	–	1?	5?	-11.2	1590 ± 600
DDO 210	(Aquarius)	–	0	–	-9.9	800 ± 250
DDO 216	(Pegasus)	–	7-10	–	-12.3	955 ± 50

[1] This work

a search for variable stars with shorter periods ranging from ~ 1.5 days up to ~ 10 days.

The acquired data were bias subtracted, flat-fielded and cosmic ray rejected. Then, the images from one night were astrometrically aligned to a common reference frame and combined with individual weights proportional to their S/N. For each epoch, consisting of all the stacked images of a single night, a difference image against a common deep reference frame was created using an implementation (Gössl & Riffeser, 2002, 2003) of the Alard algorithm (Alard & Lupton, 1998). Finally, these difference images were convolved with a stellar PSF.

To extract lightcurves from the reduced data, first all pixels deviating significantly (3σ) from the reference image in a minimum number of epochs n were flagged, utilizing the complete per-pixel error propagation of our data reduction pipeline. Then, using these coordinates as input, values and associated errors are read from the difference images and the lightcurve data are assembled. To search for periodic signals in the extracted difference fluxes, a Lomb (1976) algorithm using the interpretation from Scargle (1982) is applied.

The photometric calibration was conducted using the HST data published by Schulte-Ladbeck et al. (2003).

3. Preliminary Results

For the galaxies Leo A, and UGCA 92, we have a very good monitoring and a large fraction of the data passed already the pipeline. The Leo A data set serves as test case: A total of 26 variable star candidates were detected. Among them, we identified 16 secure long period variables (typical average values $19.4 < R < 22.1$, and $74 <$ period [days] < 590), and we have 8 further candidates for LPVs. In addition we were able to identify two good candidates for δ Cephei stars with best fitting periods of 6.4 and 1.69 days. The later candidate was previously described by Dolphin et al. (2002) as C2-V58 with a period of 1.4 days. The Dolphin et al. period solution fails in deriving a reliable lightcurve with our data, yet, applying our period value to their data set yields reasonable results. The phase convolved lightcurves for the two δ Cephei variables are shown in Figure 1.

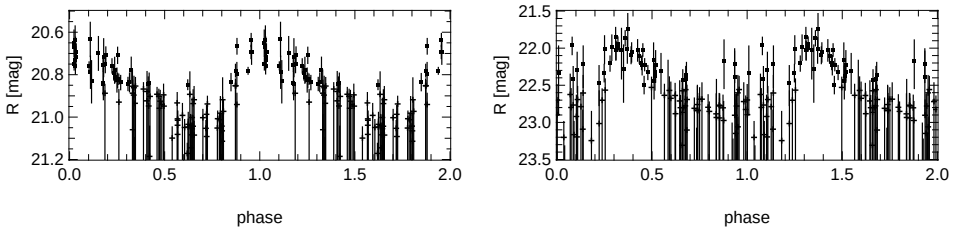

Figure 1. Phase convolved lightcurves for two Cepheids found in the Leo A dwarf galaxy. Plotted are the apparent *R*-Band magnitudes against twice the phase. The left panel shows a Cepheid with 6.4 days period. In the right panel a Cepheid with a period of 1.69 days is shown, that was previously published by Dolphin et al. (2002) with a period of 1.4 days.

4. Comparison with published work

The color magnitude diagram shown in the left panel of Figure 2 is based upon the HST data published by Tolstoy et al. (1996) and Schulte-Ladbeck et al. Flagged by bigger symbols are those variables from our sample that lie inside the HST field of view, two δ Cephei variables in the instability strip (crosses) and the candidates for long term variability (triangles) in the regime of the red giants.

Tolstoy et al. (1996) based on ground-based data found a distance modulus for Leo A of 24.2 and a resulting distance of 690 kpc (see also Schulte-Ladbeck et al.). This result got further support by the search for short periodic variables with the WIYN telescope within 3 consecutive days in Dec. 2000 (Dolphin et al. 2002). Our data complement this dataset for longer periods.

The right hand panel of Figure 2 shows the period-luminosity (PL) relation of the SMC shifted to the distance determined by Tolstoy et al. The short period variables measured by Dolphin coincide with the shown PL relation. The overplotted values for the two Cepheids from our survey (crosses) support this relation also in the regime of longer periods.

5. Summary

We presented preliminary results for our survey for variable stars in a sample of irregular local group dwarf galaxies. For the Leo A dwarf galaxy, the best analysed case so far, we already identified a total of 26 candidates for variability, 16 of these as long period variables and 2 δ Cephei stars. We compared the later with the period-luminosity relation and the short period variables discussed by Dolphin et al. (2002). We found, that our Cepheids fully support their findings and the resulting distance estimate for Leo A. This result is further in good agreement with the TRGB distance (Tolstoy et al., Schulte-Ladbeck et al.). The location of the LPVs in the color-magnitude diagram indicate that most of them are early asymptotic giant branch stars. While a complete census of these intermediate age stars is missing for most of the Local Group members, a proper statistic of their appearance can guide the reconstruction of the

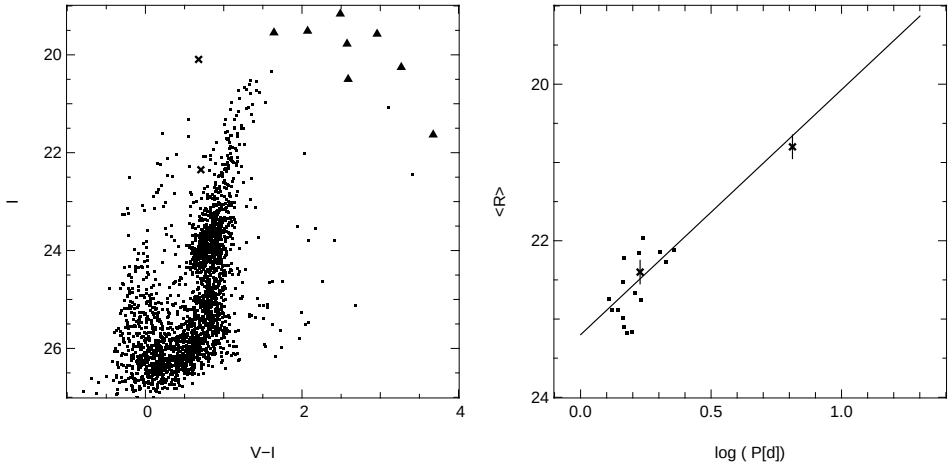

Figure 2. The left hand panel shows a color-magnitude diagram based on HST observations by Schulte-Ladbeck et al. (2003). Overplotted the secured variables in Leo A with positions falling into the field of view of the HST observations. The right hand panel shows the period-luminosity relation of the SMC shifted to the distance determined by Tolstoy et al. (1996). The small dots mark the Cepheids found by Dolphin et al. (2002), the large crosses the two Cepheids presented here.

star formation history at the age of several Gyr by-passing the age metalicity degeneracy inherent to color magnitude diagram studies.

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